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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G02B 27/14, 5/08	A1	(11) International Publication Number: WO 91/06031 (43) International Publication Date: 2 May 1991 (02.05.91)

(21) International Application Number: PCT/US90/05901

(22) International Filing Date: 15 October 1990 (15.10.90)

(30) Priority data:
422,141 16 October 1989 (16.10.89) US
587,459 27 September 1990 (27.09.90) US

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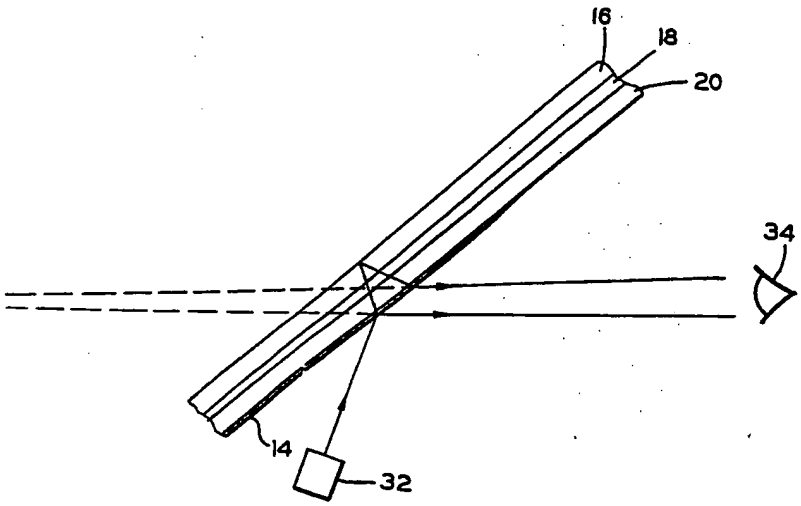
(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: DISPLAY PANEL FOR A VEHICLE WINDSHIELD



(57) Abstract

A vehicle winshield, for use in a head-up display system, comprises a laminated windshield assembly (10), wherein the laminated windshield interlayer geometry causes a primary image reflected from the inboard surface (20) and a secondary image reflected from the outboard surface (16) of the windshield to be substantially superimposed, thereby presenting a singular image to the vehicle operator. A patch (14) of reflective material may be disposed on the inboard surface (20) of the assembly (10) to enhance the contrast between the reflected image and the background.

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Description

DISPLAY PANEL FOR A VEHICLE WINDSHIELD

Field of the Invention

This invention relates generally to display panels for vehicle windshields, and more particularly, to a display panel integral with an automotive windshield, for the head-up monitoring of vehicle operating information.

Background of the Invention

Head-up display panels are commonly used in systems for projecting vehicle operating information onto a vehicle windshield, for reflecting images into the operator's forward field of vision. The operator can thereby simultaneously view the area in front of the vehicle and the displayed information. Various head-up display systems are currently utilized in the aircraft industry.

A head-up display system in an automobile minimizes the operator's need to divert his attention from observation of the road to periodic observation of the dashboard display panel. Such a system, which allows an operator to continuously focus his attention on the road and simultaneously view essential vehicle operating information, greatly enhances the safety of vehicle passengers and others.

While the advantages of head-up displays are apparent, the use of such displays in automobiles will become widespread only if they can be integrated into the vehicle windshield manufacturing process, within the stringent cost and quality requirements of the automotive industry. The head-up display systems currently used in the aircraft industry are overly sophisticated and prohibitively expensive for use in automobiles. For example, United States Patent No. 4,775,218 to Hodel et al. discloses a head-up display system comprising a movable combiner supported on brackets and positioned in the operator's forward line-of-sight. The display emanates from a stationary source and is projected

onto a preselected position on the combiner, which is configured so that the display symbology is superimposed on the "real world" scene. Means for detecting the orientation of the combiner, relative to the image source, triggers a realignment of the combiner to maintain the preselected position of the display. The complexity and expense of such a system render it impractical for use in an automobile.

It is well known that laminated glazing units, as employed in the windshields of automobiles, are generally produced by integrally bonding two sheets of glass to an interposed layer of plastic. The plastic interlayer material almost universally employed is polyvinyl butyral. Normally, the plastic interlayer material is differentially stretched to match the curvature of the associated glass sheets. Two such methods are described in United States Patent No. 3,912,440 to Koss et al. and United States Patent No. 4,554,713 to Chabal.

The aforementioned automotive glazing units are not entirely satisfactory for use with a head-up display panel, however, for at least two reasons. Firstly, the geometry of the known glazing unit causes a reflection off the outboard surface of the windshield to appear as a secondary display image. The displacement between the secondary display image and the primary display image reflected off the inboard surface of the windshield may make the display symbology very difficult to decipher. Secondly, the relatively high transmissivity and low reflectance of the known glazing units produce a primary display image with low contrast under bright light conditions. Obviously, it is necessary that the display image be clearly visible under all ambient light conditions.

It would be desirable to manufacture an automobile windshield having an integral head-up display panel, which would allow the viewing of essential operating information under all ambient light conditions, with minimal distortion

of the displayed images due to displacement between the primary and any secondarily displayed images.

Summary of the Invention

There is thus provided in accordance with the present invention a vehicle windshield for use with a head-up display system which markedly improves the image display as viewed by the vehicle operator. The novel windshield comprises an outboard sheet of glass, including a first, outboard or outwardly facing surface and a second surface opposite the first surface, a transparent interlayer including a first surface adjacent and adhered to the second surface of the outboard sheet of glass and a second surface opposite the first surface, with the interlayer having a predetermined wedge angle. An inboard sheet of glass includes a first surface adjacent and adhered to the second surface of the interlayer and a second, inboard or inwardly facing surface. A reflectance increasing patch of a metal oxide coating may be adhered to a portion of the inboard surface of the inboard glass sheet and positioned so as to be in the line-of-sight of an operator of the vehicle. The interlayer is disposed within the windshield with the wedge extending transversely thereof and tapering inwardly from the upper toward the lower regions of the head-up display viewing area. The interlayer wedge angle is selected pursuant to the anticipated installation angle of the windshield, thickness of the glass sheets, and angle of incidence of the projected image, so as to substantially superimpose the reflected images generated from a dashboard display device and reflected from the inboard surface or patch of the inboard sheet and from the outboard surface of the outboard sheet into a substantially singular image in the eyes of the vehicle operator.

The vehicle windshields of the present invention are useful for providing the head-up display of operating information for the operator of a vehicle.

Also provided in accordance with this invention is a method of producing a windshield for a head-up display system of a vehicle, said windshield including a transparent interlayer disposed between an outboard sheet of glass and an inboard sheet of glass, comprising the steps of calculating the wedge angle at which the outboard and inboard sheets of glass are to be disposed in said vehicle head-up display system to cause primary and secondary reflected images of the display as viewed by a vehicle operator to be substantially superimposed, forming an interlayer sheet whose opposite major surfaces are disposed at substantially said calculated wedge angle to one another, assembling said interlayer sheet between said outboard and inboard sheets of glass, and laminating the assembly to secure said outboard and inboard sheets to said interlayer whereby said outboard and inboard sheets are disposed at said calculated wedge angle to one another.

Brief Description of the Drawings

In the accompanying drawings:

Fig. 1 is a perspective view of a windshield including a heads-up display panel, embodying the features of the present invention;

Fig. 2 is an enlarged, fragmentary, cross-sectional view, taken along line 2-2 of Fig. 1, illustrating the laminated glazing and the patch of metal oxide adhered thereto; and

Fig. 3 is a schematic representation of the operation of the windshield of Fig. 1.

Detailed Description of the Preferred Embodiment

Referring now to Fig. 1, there is shown generally at 10, a windshield embodying the features of the present invention. The windshield 10 comprises a laminated glazing 12 upon which a patch 14 of a reflecting material may be deposited to

enhance visibility for the vehicle operator as will be hereinafter described.

As best seen in Fig. 2, the laminated glazing 12 includes an outboard sheet of glass 16, a transparent interlayer 18, and an inboard sheet of glass 20. The outboard sheet of glass 16 includes a first, outboard surface 22 and a second surface 24 opposite the first surface 22. The inboard sheet of glass 20 includes a first surface 26, and a second, inboard surface 28 opposite the first surface 26. The transparent interlayer 18 is interposed between the outboard sheet of glass 16 and the inboard sheet of glass 20. A first surface of the interlayer 18 is adjacent and adhered to the second surface 24 of the outboard sheet of glass, and a second surface of the interlayer 18 opposite the first surface is adjacent and adhered to the first surface 26 of the inboard sheet of glass 20. As a result of their lamination to the transparent interlayer 18, the surfaces 24 and 26 are effectively eliminated as optically reflecting elements.

The patch 14 of reflecting material is optionally formed on a portion of the inboard surface 28 of the inboard glass sheet 20. It is positioned, as best seen in Fig. 1, so as to be directly in the line-of-sight of a person operating the vehicle and looking ahead of the vehicle through the windshield. The patch 14 may, for example, comprise a coating of a reflecting material such as a metal oxide, which has a reflectance greater than that of the uncoated glass surrounding the patch 14. While there is no specific thickness nor density required for the coating, the term "reflectance increasing", as used herein, means that the coating must be sufficient to increase the reflectance of the coated surface over the uncoated inboard surface 28 of the inboard sheet of glass 20. The reflectance increase caused by the patch 14 results in a higher contrast ratio, the contrast ratio being equal to the intensity of the primary reflected image divided by the intensity of the outside

image, and therefore in higher visibility for the vehicle operator. A contrast ratio of at least 1.8 is desirable. It is usually undesirable, however, to use a coating so thick that it adds color interference or iridescence to reflected or transmitted light.

The patch 14 preferably is provided with a fade-out region 30, which immediately surrounds the periphery of the patch 14. In the fade-out region 30, the density of the metal oxide coating gradually decreases with increased distance away from the patch 14, thereby resulting in a correspondingly gradual diminution of the reflectance of the metal oxide coating. Again, it is undesirable for the thickness of the coating to be such as to cause color interference or iridescence across the fade-out region. The fade-out region 30 minimizes the distraction to the driver caused by the higher reflectance of the patch 14, relative to the reflectance of the laminated glazing 12, which would otherwise result from an abrupt boundary between the patch 14 and the uncoated inboard surface 28 of the inboard sheet of glass 20. The patch 14 may conveniently be of any size or shape, as dictated by the configuration and quantity of information to be displayed.

The geometry of the transparent interlayer 18 is generally defined as wedge-shaped, meaning that the distance between the first and second surfaces of the interlayer 18 decreases when measured at various points from the top of the laminated glazing 12 to the bottom. The wedge-shaped characteristic of the interlayer may be expressed in terms of the wedge angle, created by intersecting planes parallel to the first and second surfaces of interlayer 18. The appropriate wedge angle for a given application is a function of the windshield 10 installation angle, the glass thickness, and the angle of incidence of the projected image. Typically, the wedge angle varies between greater than zero and about 0.025° or more.

In operation, as depicted in Fig. 3 an image which is intended to relate a vehicle operating parameter or any other piece of information, is projected at a predetermined angle of incidence relative to the inboard surface 28 from a dashboard display device, shown diagraminatically at 32, onto the inboard surface 28 or onto the patch 14 of reflective material as the case may be It is then reflected as the primary image to the eyes 34 of the vehicle operator. The dashboard display device 32 may comprise, for example, an illuminated or LED display, which is projected through an appropriate optical system either onto the patch coating 14 or directly onto the inboard surface 28 of the inboard glass sheet 20. A secondary image is simultaneously reflected from the outboard surface 22 of the outboard sheet of glass 16 toward the eyes of the operator. Utilizing the proper combination of windshield 10 installation angle, image projection angle, and interlayer 18 wedge angle, the primary and secondary images are substantially superimposed so as to appear as a singular image when observed by the vehicle operator. An angular displacement of less than about 0.025° between the primary and secondary images, as appearing to the eyes 34, causes the images to appear as a substantially singular image in the eyes of the vehicle operator. The reflectance increasing properties of the patch 14 will result in a higher contrast ratio between the primary and secondary images, equal to the intensity of the primary reflected image divided by the intensity of the secondary reflected image.

The glass sheets 16 and 20 suitable for use in manufacturing the windshields 10 according to the present invention may include any of the conventional glass substrates known in the art as useful for the preparation of laminated vehicle windshields.

The transparent interlayer 18 useful for the present invention may be prepared from conventional laminated glass interlayer materials such as, for example, polyvinyl butyral, plasticized polyvinyl chloride, multilayered thermoplastic

materials including polyethylene terephthalate, etc. Suitable interlayer materials are more fully set forth in U.S. Patents, Nos. 4,287,107 and 3,762,988, which are incorporated herein in their entirety by reference thereto. A preferred transparent interlayer material is polyvinyl butyral.

As heretofore indicated a number of factors, including the windshield installation angle, the image projection angle, the observers viewing position,and the interlayer wedge angle, determine the display image presented to the vehicle operator. Thus, if the combined effect of these factors is to produce a secondary image which appears to the observer to be substantially displaced from the primary image, the resulting display will be annoying and difficult to read. In accordance with the invention, this condition is corrected, or at least the effect is minimized, by fabricating, the windshield with an interlayer 18 having a wedge angle which results in the surfaces 22 and 28 being disposed at an angle which consequently causes the secondary image to converge toward the primary image as illustrated in Fig. 3.

While it would be desirable to have the secondary image precisely superimposed upon the primary image, achieving such a condition may be a practical impossibility in the mass production of the many models of vehicles for unknown potential drivers. It has been discovered that a limited amount of displacement of the secondary image can be accommodated without unduly detracting from the clarity of the displayed image. Thus, it has been found that an interlayer wedge angle intermediate the theoretical ideal angles for various models of automobiles will bring the displacement of the secondary image in HUD systems of most current and anticipated vehicle models within an acceptable range. HUD systems for particular types of vehicles having image displacement of acceptable levels may likewise employ windshields fabricated with interlayers having a limited

range of wedge angles. By way of example, windshields having an interlayer wedge angle between about 0.006° and 0.046° produce a suitable display image in most HUD installations. An interlayer with a wedge angle of about 0.025° has been found very suitable for producing HUD windshields adaptable to a wide range of vehicle models wherein the secondary image of the display will be closely superimposed upon the primary image.

As disclosed in U.S. Patents Nos. 3,912,440 and 4,554,713, among others, it has been known to expand vinyl material which is used in laminating glass sheets together in forming an automotive windshield. Such stretching of a plasticized polyvinyl butyral web used to form the interlayer of automotive windshields is employed when a tinted or gradient band is to be located across the top of the windshield for the purpose of reducing the amount of glare encountered by the vehicles' front seat occupants of the vehicle. As explained in the aforementioned patents, the stretching or deforming is necessary so that upon lamination of the glass sheets to the interlayer and installation of the windshield in a vehicle, the lower edge of the gradient band will appear as a straight line across the windshield.

Such deforming or expanding, of course, results in formation of a certain amount of thickness gradient, or wedge, across the interlayer. While a similar procedure may be used for forming a transparent interlayer having a wedge-shaped configuration for use with the present invention, it has been found that an interlayer produced by such stretching of the plasticized material is not entirely satisfactory for use in the invention. Thus, the stretched material does not exhibit a uniform thickness gradient transversely across the web. Instead, the stretching has been found to result in random thickness variations transversely across the interlayer, as well as in directions disposed at an angle to the direction of stretching. In other words, the direction and magnitude of the interlayer wedge are not uniform. As a

result, the degree of visual clarity which can be attained in superimposing the secondary image upon the primary image is adversely affected.

Applicants have discovered that this condition can be alleviated by utilizing as the transparent interlayer 18 a sheet of interlayer material which has been extruded with the desired wedge angle between its opposite surfaces, so that subsequent stretching or expanding is unnecessary. The interlayer can thus be formed with the particular wedge angle desired and with a uniform straight line thickness variation across the interlayer. The extruded sheet likewise exhibits constant thickness in the longitudinal direction. The interlayer may be extruded with a precise predetermined wedge angle to produce in a windshield fabricated therefrom a high degree of optical uniformity. For example, the interlayer material may have the aforementioned wedge angle of 0.025° found particularly suited for fabricating windshields for HUD systems installed in many automobiles. It is, of course, important in fabricating windshields having a wedged interlayer in accordance with the invention, that the unit be adapted to employment of conventional fabricating techniques such as use of peripheral vacuum rings for de-airing, passage through nip rolls, autoclaving, etc. To that end it has been found that units utilizing a wedged interlayer in accordance with the invention may be fabricated in accordance with conventional laminating procedures.

The process utilized for forming the inboard and outboard glass sheets 20 and 22, respectively, and the transparent interlayer 18 into the laminated glazing 12 useful for manufacturing the windshields 10 of the present invention, may be any of the processes known generally in the art for producing laminated vehicle windshields. Such processes are described, for example, in U.S. Patents Nos. 3,708,386 and 3,900,673, which are incorporated herein in their entirety by reference thereto.

A reflective patch 14, for example a metal oxide coating may be deposited on the laminated glazing 12, thereby forming the reflective display panel. Useful coatings are chromium oxide, tin oxide, aluminum oxide, zinc oxide, nitrides and the like. A preferred metal oxide is chromium oxide.

The reflective coating may be applied to a portion of the inboard surface 28 of the inboard glass sheet 20 by conventional coating techniques such as, for example, chemical vapor deposition or reactive sputtering of a metal or metal oxide. A particularly useful method includes the cathode atomization sputtering of the metal oxide coating onto the inboard surface 28, utilizing a mask or shutter arrangement to define the size and shape of the patch 14. The mask or shutter is conveniently superposed relative to the inboard surface 28 of the inboard glass sheet 20, so as to cause overspray at the peripheral edges of the patch 14, thereby forming the fade-out region 30 of the display panel. Specific methods for sputter coating a metal oxide onto glass utilizing masks or shutters are described fully in U.S. Patent Nos. 4,562,093 and 4,278,528, which are incorporated herein in their entirety by reference thereto.

The process of the present invention generally involves the aforementioned steps of assembling and laminating together an outboard sheet of glass 16, an inboard sheet of glass 20, and a wedge-shaped sheet of transparent interlayer material 18 therebetween. The patch 14 of reflective material may then be applied to the laminated glazing 12. It must be noted that the process conditions are not sharply critical for the successful manufacture of the windshields 10 of the present invention. The process conditions described hereinabove are generally disclosed in those terms which are conventional to the practice of this invention. Occasionally, however, the process conditions as described may not be precisely applicable for each embodiment included within the disclosed scope. Those situations for which this occurs will be readily recognizable by those ordinarily

skilled in the art. In all such cases, either the process may be successfully performed by conventional modifications known to those ordinarily skilled in the art, e.g., by utilizing different reflective coatings to form the display panel, by employing different coating techniques such as spray coating, by including additional layers of glass or thermoplastic in the laminated glazing 12, etc., or other process variables which are otherwise conventional will be applicable to the practice of this invention.

Comparison 1

A laminated glazing is manufactured utilizing two glass sheets and a polyvinyl butyral transparent interlayer of uniform thickness therebetween. A patch of zinc oxide having a height of about 14 inches and a width of about 5.5 inches is sputter coated onto the inboard surface of the laminated glazing. The transmissivity of the coated area is about 70% while the transmissivity of the uncoated laminated glazing is about 77%. A fadeout region extends away from the periphery of the patch about 1.5 inches.

The windshield with the display panel is installed at an angle of about 27° from vertical, and light from the display device is projected onto the zinc oxide coating at an angle of incidence of about 68.75°.

The resulting primary and secondary images are displaced by 119 mils at a distance from the windshield of about 94.5 inches. The corresponding angular displacement of the images is about 0.072°, which appears as a double or blurred image to the operator.

Example I

A windshield is prepared and installed, and the procedures repeated, as described in Comparison 1, excepting that a wedge-shaped interlayer of polyvinyl butyral is employed according to the present invention. The interlayer sheet has a thickness at the top of the laminated glazing

about 10 mils greater than at the bottom, a distance of about 36 inches, resulting in a wedge angle of about 0.0155°.

The displacement between the primary and secondary images is about 11 mils at a distance of about 94.5 inches. The corresponding angular displacement is about 0.007°. This amount of angular displacement presents a substantially singular image to the vehicle operator.

The aforementioned procedures are repeated, yielding the following results:

Table I

Performance Parameters

	Comp. 2	Exam. 2	Comp. 3	Exam. 3
Variation in Inter-Layer Thickness	0	7 mils per 36"	0	5 mils per 36"
Interlayer Wedge Angle	0	0.0110°	0	0.0085°
Windshield Intallation Angle	23°	23°	27°	27°
Projection Angle of Incidence	72.75°	72.75°	68.75°	68.75°
Displacement of Primary & Secondary Images	101 mils @ 94.5"	8 mils @ 94.5"	96 mils @ 110"	22 mils @110"
Angular Displacement	0.061°*	0.005°**	0.050°*	0.011°**

* perceived as a double or blurred image by a vehicle operator

** perceived as a substantially singular image by a vehicle operator

WHAT IS CLAIMED IS:

1. A vehicle windshield for use in a head-up display system wherein images generated from a dashboard display device are reflected from the windshield, for viewing by a vehicle operator, comprising:

A) an outboard sheet of glass including a first, outboard surface and a second surface opposite the first surface;

B) a transparent interlayer including a first surface adjacent and adhered to the second surface of the outboard sheet of glass, and a second surface opposite the first surface, the interlayer having a predetermined wedge angle; and

C) an inboard sheet of glass, including a first surface adjacent and adhered to the second surface of the interlayer, and a second, inboard surface;

D) the interlayer wedge angle being such that said outboard and inboard sheets adhered thereto are angularly disposed to cause images reflected from said outboard surface and said inboard surface to be substantially superimposed into a substantially singular image in the eyes of the vehicle operator.

2. The vehicle windshield according to claim 1, including a reflectance-increasing patch adhered to a portion of the inboard surface of the inboard glass sheet and positioned so as to be in the line of sight of the operator of the vehicle.

3. The vehicle windshield according to claim 2, wherein said reflectance-increasing patch is a metal oxide.

4. The vehicle windshield according to claim 3, wherein said metal oxide is selected from the group consisting of chromium oxide, tin oxide, aluminum oxide, and zinc oxide.

5. The vehicle windshield according to claim 4, wherein said metal oxide is chromium oxide.

6. The vehicle windshield according to claim 2, wherein said reflectance-increasing patch includes a fade-out region immediately surrounding the periphery thereof.

7. The vehicle windshield according to claim 1, wherein the wedge angle is from about 0.006° to about 0.046°.

8. The vehicle windshield according to claim 7, wherein the wedge angle is about 0.025°.

9. The vehicle windshield according to claim 1, wherein the angular displacement between the images reflected from the inboard and outboard surfaces as viewed by the vehicle operator is less than about 0.025°.

10. The vehicle windshield according to claim 1, wherein the transparent interlayer is prepared from polyvinyl butyral.

11. The vehicle windshield according to claim 1, wherein the transparent interlayer is a sheet extruded with said wedge angle.

12. The vehicle windshield according to claim 1, wherein the interlayer is a sheet of polyvinyl butyral extruded with said wedge angle.

13. A head-up display system for automotive vehicles, including a windshield and a dashboard display device for projecting a display onto said windshield, said windshield comprising an outboard sheet of glass including a first, outboard surface and a second surface opposite the first surface, a transparent interlayer including a first surface adjacent and adhered to the second surface of the outboard sheet of glass, and a second surface opposite the first surface, the interlayer having a predetermined wedge angle, and an inboard sheet of glass including a first surface adjacent and adhered to the second surface of the interlayer and a second, inboard surface, said predetermined wedge angle being selected so that images of said display reflected from said outboard and inboard surfaces are substantially superimposed to appear as a substantially singular image to the operator of the vehicle.

14. A head-up display system according to claim 13, wherein said transparent interlayer is a wedge-shaped extruded sheet having said wedge angle.

15. A head-up display system according to claim 14, wherein the wedge angle is from about 0.006° to about 0.046°.

16. A head-up display system according to claim 15, wherein the wedge angle is about 0.025°.

17. A head-up display system according to claim 13, including a reflectance-increasing patch on a portion of said inboard surface and positioned to be in the line of sight between the vehicle operator and said reflected images.

18. A head-up display system according to claim 17, wherein said transparent interlayer is a wedge-shaped extruded sheet having a wedge angle of about 0.025°.

19. A method of producing a windshield for a head-up display system of a vehicle, said windshield including a transparent interlayer disposed between an outboard sheet of glass and an inboard sheet of glass, comprising the steps of calculating the wedge angle at which the outboard and inboard sheets of glass are to be disposed in said vehicle head-up display system to cause primary and secondary reflected images of the display as viewed by a vehicle operator to be substantially superimposed, forming an interlayer sheet whose opposite major surfaces are disposed at substantially said calculated wedge angle to one another, assembling said interlayer sheet between said outboard and inboard sheets of glass, and laminating the assembly to secure said outboard and inboard sheets to said interlayer whereby said outboard and inboard sheets are disposed at said calculated wedge angle to one another.

20. A method of producing a windshield according to claim 19, including the step of extruding said interlayer sheet with its surfaces disposed at said calculated wedge angle.

21. A method of producing a windshield according to claim 19, including the step of depositing a reflectance-increasing patch onto a portion of the exposed surface of said inboard glass sheet in a position so as to be in the line of sight of an operator of the vehicle.

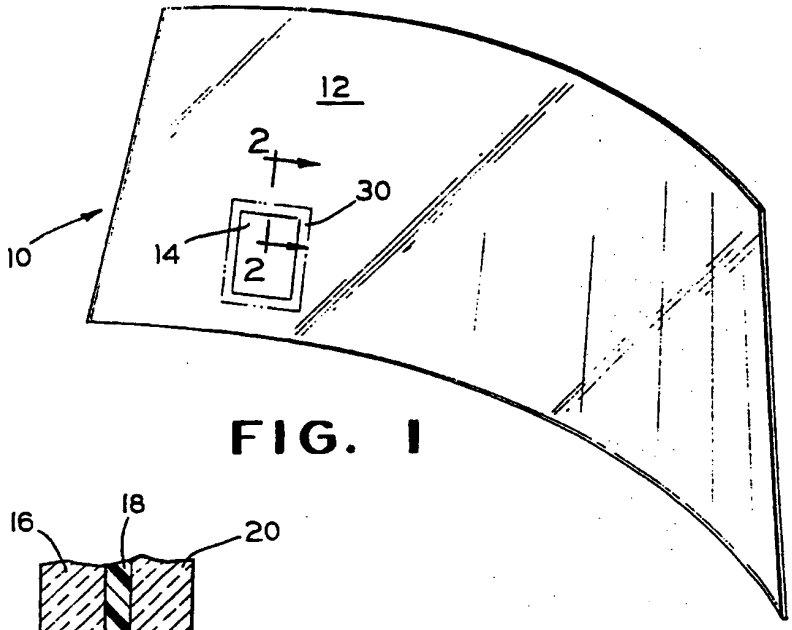

FIG. 1

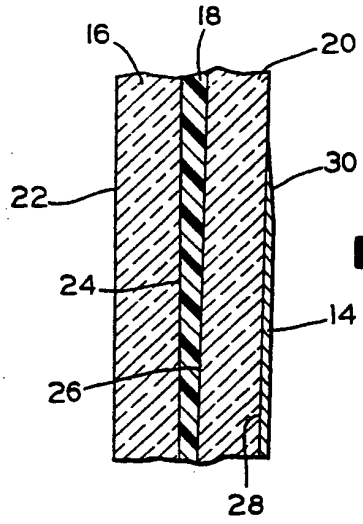

FIG. 2

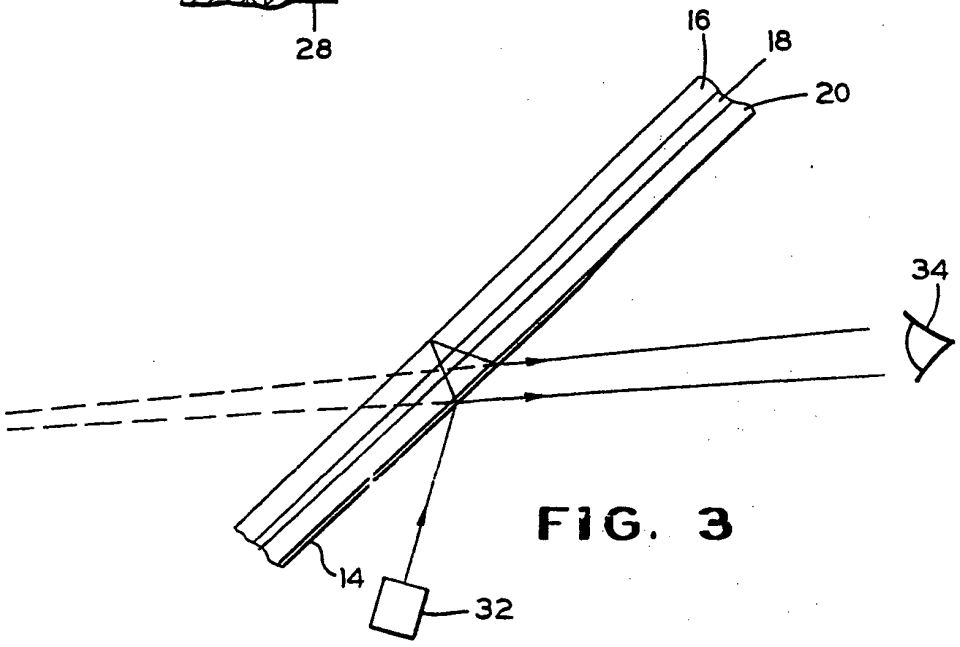

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/05901

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): G02B 27/14; G02B 5/08
US CL.: 350/174; 350/641

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	350/1.6,1.7,3.6,3.63,3.85,162.18,589,590,641,642; 425/302.1,363,364,365,366; 156/99,102,556; 427/160,163,166; 428/409,437; 350/172,174

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 3,899,241 (MALOBICKY, JR. et al.) 12 August 1975, See the entire document.	1-21
Y	US, A, 3,912,440 (KOSS et al.) 14 October 1975 Columns 3-6, Figs. 1 and 3.	19-21
A	US, A, 4,325,609 (ALFORD) 20 April 1982 See columns 2-4 and Fig. 3.	1-21
A	US, A, 3,900,673 (MATTIMOE et al.) 19 August 1975 See the entire document.	1-21
A	JP, A, 63-311201 (IMAMURA) 20 December 1988 See the entire document.	1-21
A	US, A, 4,694,332 (UCHIDA) 15 September 1987 See columns 2-4 and Figs 1-2.	1-21
A	US, A, 4,943,140 (WOODARD et al.) 24 July 1990 See the entire document.	1-21
Y	US, A, 4,787,711 (SUZUKI et al.) 29 November 1988 See the entire document.	1-21

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
26 DECEMBER 1990	04 FEB 1991
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	B.Y. ARNOLD